EXECUTIVE SUMMARY

In order to better achieve and maintain water quality conditions necessary to protect aquatic living resources of Chesapeake Bay and its tidal tributaries, the U.S. Environmental Protection Agency (EPA) Region III has developed guidance titled ***Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries*** *(Criteria Guidance)*. This *Criteria Guidance* is intended to assist the Chesapeake Bay states, Maryland, Virginia, and Delaware, and the District of Columbia in adopting revised water quality standards to address nutrient and sediment-based pollution in Chesapeake Bay and its tidal tributaries.

EPA Region III developed this *Criteria Guidance* to promote the overall goals of the Clean Water Act and specifically in accordance with the EPA National Strategy for the Development of Regional Nutrient Criteria announced in June 1998. This national nutrient strategy laid out EPA's intentions to develop technical guidance manuals for four types of waters (lakes and reservoirs, rivers and streams, estuaries and coastal waters and wetlands) and to produce criteria for specific nutrient ecoregions (www.epa.gov/ost/standards/nutrient.html). In addition, EPA works with the states and tribes to develop more refined and localized nutrient and nutrient-enrichment related criteria based on approaches described in the water body guidance manuals. This *Criteria Guidance* provides the regional nutrient guidance applicable to Chesapeake Bay and its tidal tributaries.

EPA Region III has developed this *Criteria Guidance* using the multi-stakeholder approach to implementing the *Chesapeake 2000* agreement. The *Chesapeake 2000* agreement was signed on June 28, 2000, by the governors of Maryland, Pennsylvania and Virginia, the mayor of the District of Columbia, the chair of the Chesapeake Bay Commission and the Administrator of the U.S. EPA. Subsequently, the governors of Delaware, New York and West Virginia signed a Memorandum of Understanding committing to implement the Water Quality Protection and Restoration section of the *Chesapeake 2000* agreement.

The water quality criteria and tidal water designated uses presented in this document are the product of a collaborative effort among the Chesapeake Bay Program partners. They represent a scientific consensus based on the best available scientific findings and technical defining water quality conditions necessary to protect Chesapeake Bay aquatic living resources from effects due to nutrient and sediment over enrichment. Various stakeholder groups have been involved in their development, with contributions from staff of federal and state government, local agencies, scientific institutions, citizen conservation groups, business and industry.

In this *Criteria Guidance* EPA recommends and expects that the numerical criteria and refined designated aquatic life uses will be considered by and appropriately incorporated into the water quality standards of the Chesapeake Bay jurisdictions with tidal waters–Maryland, Virginia, Delaware, and the District of Columbia. Using the existing state authority and public process, each jurisdiction is expected to consider and propose criteria and appropriate designated uses subject to review and approval or disapproval by EPA consistent with the requirements of the

Clean Water Act. EPA will consider the *Criteria Guidance* in reviewing any state submission regarding this issue. The guidance contained in this document is subject to change.

REFINED DESIGNATED USES: ESSENTIAL AQUATIC LIFE COMMUNITIES

EPA Region III has identified and described five habitats (or designated uses) that when adequately protected will ensure the protection of the living resources of Chesapeake Bay and tidal tributaries. Those five uses (described below) provide the context in which EPA Region III derived adequately protective Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll *a* (see Figure 1) that are the subject of this *Criteria Guidance*. Accurate delineation of where to apply these tidal water designated uses is critical to the Chesapeake Bay water quality criteria. EPA Region III has published a *Technical Support Document for the Identification of Chesapeake Bay Designated Uses and Attainability* which provides further information on the development and geographical extent of the designated uses to which the criteria may apply.

The *migratory fish spawning and nursery designated use* protects migratory fish during the late winter to late spring spawning and nursery season in tidal freshwater to low-salinity habitats. Located primarily in the upper reaches of many Bay tidal rivers and creeks and the upper mainstem Chesapeake Bay, this use will benefit several species including striped bass, perch, shad and herring.

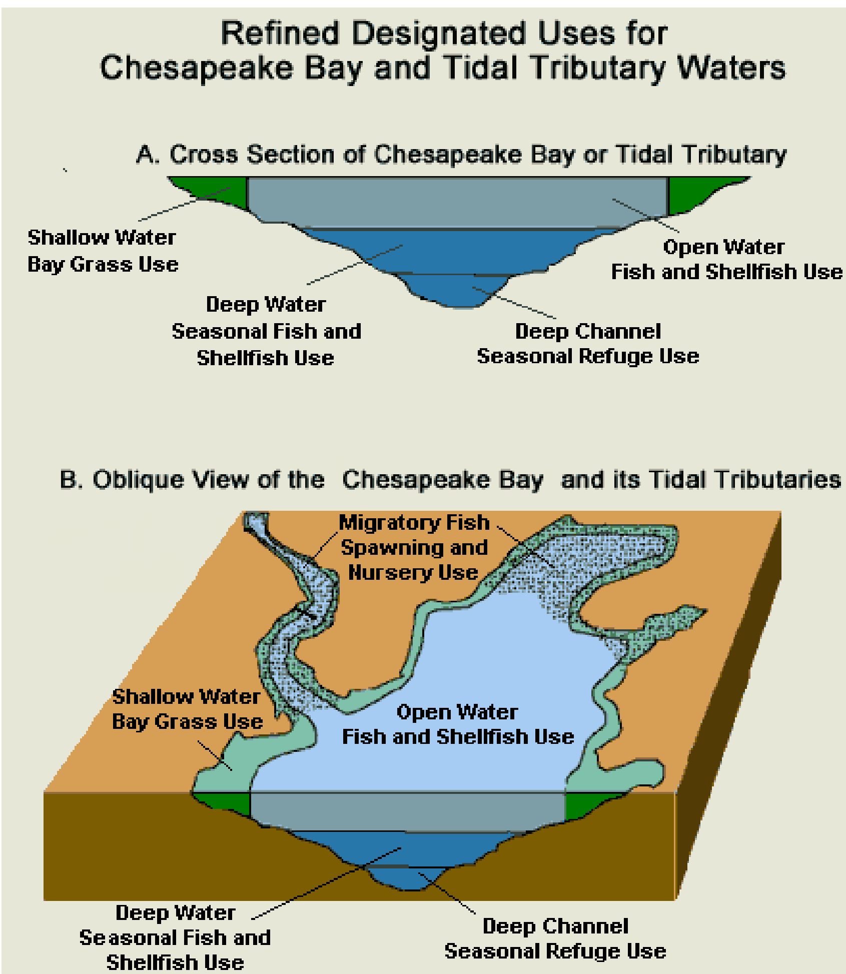

Figure 1. Conceptual illustration of the five Chesapeake Bay tidal water designated use zones.

The *shallow-water bay grass designated use* protects underwater bay grasses and the many fish and crab species that depend on the vegetated shallow-water habitat provided by underwater grass beds.

The *open-water fish and shellfish designated use*, focuses on surface-water habitats in tidal creeks, rivers, embayments and the mainstem Chesapeake Bay, and protects diverse populations of sport fish, including striped bass, bluefish, mackerel and sea trout, as well as important bait fish such as menhaden and silversides.

The *deep-water seasonal fish and shellfish designated use* protects animals inhabiting the deeper transitional water-column and bottom habitats between the well-mixed surface waters and the very deep channels. This use protects many bottom-feeding fish, crabs and oysters, and other important species such as the bay anchovy.

The *deep-channel seasonal refuge designated use* protects bottom sediment-dwelling worms and small clams that bottom-feeding fish and crabs consume in the very deep channel. Low dissolved oxygen conditions prevail in the deepest portions of this habitat zone, and will naturally have very low to no dissolved oxygen during the summer.

The Chesapeake Bay watershed states with tidally influenced Bay waters–Maryland, Virginia, Delaware and the District of Columbia–are ultimately responsible for defining and formally adopting a refined set of designated uses into their respective water quality standards.

DISSOLVED OXYGEN CRITERIA

Oxygen is one of the most essential environmental constituents supporting life. In the Chesapeake Bay's deeper waters, there is a natural tendency toward reduced dissolved oxygen conditions because of the Bay's physical morphology and estuarine circulation. The Chesapeake Bay's highly productive shallow waters, coupled with strong density stratification, long residence times (weeks to months), low tidal energy and its tendency to retain, recycle and regenerate nutrients from the surrounding watershed, all set the stage for low dissolved oxygen conditions. Against this backdrop, EPA Region III has derived a set of dissolved oxygen criteria to protect specific aquatic life communities (outlined above) and reflect the Chesapeake Bay's natural processes and habitats (Figure 1).

The derivation of these criteria followed EPA national guidelines and the risk-based approach used in developing the EPA's Virginian Province saltwater dissolved oxygen criteria (for estuarine and coastal waters from Cape Cod, Massachusetts to Cape Hatteras, North Carolina). The resulting criteria reflect the needs and habitats of Chesapeake Bay estuarine living resources,and are structured to protect five tidal-water designated uses (Figure 2).

Criteria for the migratory fish spawning and nursery, shallow-water bay grass and open-water fish and shellfish designated uses were set at levels to prevent impairment of growth, and to protect the reproduction and survival of all organisms (Table 1). Criteria for deep-water seasonal fish and shellfish designated use habitats during seasons when the water column is significantly stratified were set at levels to protect juvenile and adult fish, shellfish and the recruitment success of the bay anchovy. Criteria for deep-channel seasonal refuge designated use habitats in summer were set to protect the survival of bottom sediment-dwelling worms and clams. These deep-water and deep-channel criteria take into account the natural historic condition of low dissolved oxygen in these habitats resulting from the physical characteristics of the Chesapeake Bay system. They also assume that some degree of low dissolved oxygen may continue to persist in these habitats in the future.

Figure 2. Dissolved oxygen (mg liter^{-1}) concentrations required by different Chesapeake Bay species and communities.

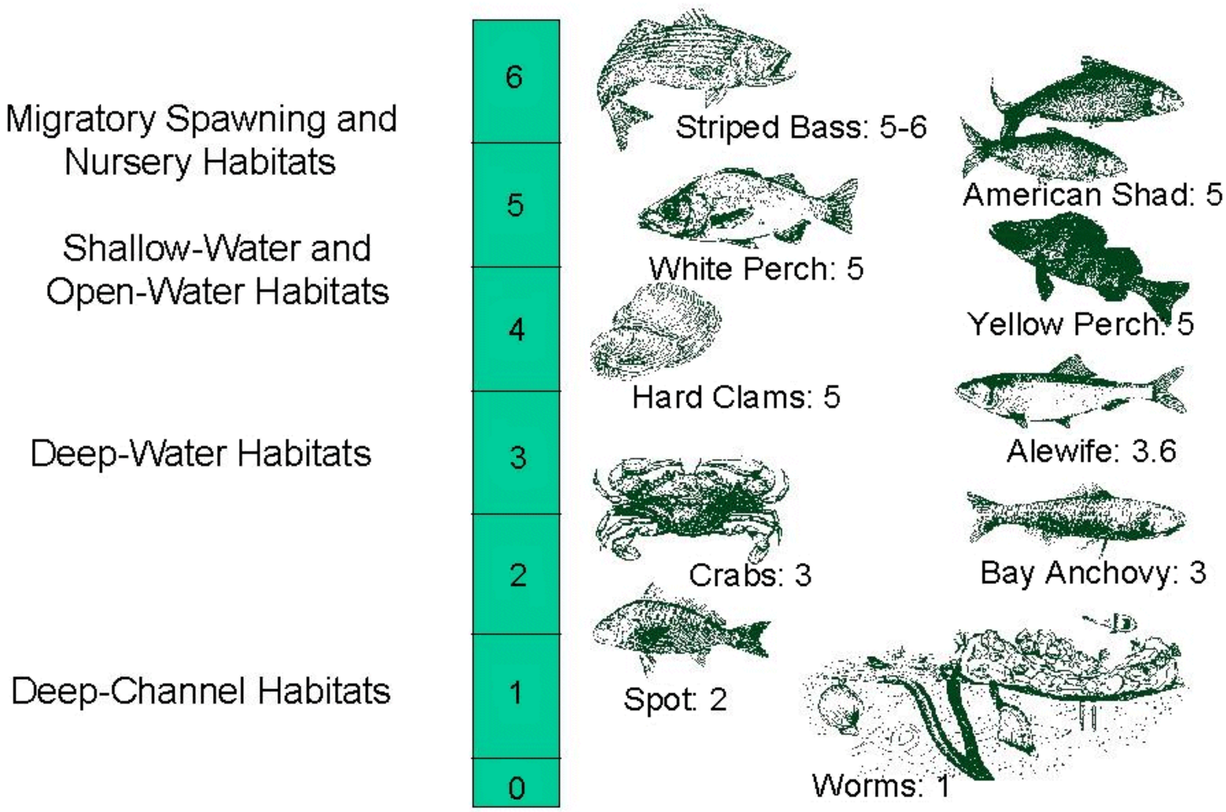

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larvae/juvenile tidal-fresh resident fish.	February 1 - May 31
	Instantaneous minimum $\geq$ 5 mg liter^{-1}	Survival and growth of larvae/juvenile migratory fish.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of juvenile and adult fish and shellfish.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival/growth of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3 mg liter^{-1}	Survival of threatened/endangered sturgeon species.	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter^{-1}	Survival/recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open water fish and shellfish designated use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Incidence of sustained, periodic anoxic (< 0.2 mg liter^{-1}) conditions acceptable. (applies to the seasonal anoxic region only)	Survival of meiofaunal organisms (e.g., nematode worms) and bacteria important to biogeochemical cycles.	July 1 - August 31
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

WATER CLARITY CRITERIA

Underwater bay grass beds in the Chesapeake Bay create rich animal habitats that support the growth of diverse fish and invertebrate populations. Bay grasses help improve tidal water quality by retaining nutrients as plant material, stabilizing bottom sediments (preventing their resuspension) and reducing shoreline erosion. The health and survival of these plant communities in Chesapeake Bay and its tidal tributaries depend on suitable environmental conditions. The loss of SAV from the shallow waters of the Chesapeake Bay, which was first noted in the early 1960s, is a widespread, well-documented problem. The primary causes of the decline of these underwater bay grasses are nutrient over-enrichment and increased suspended

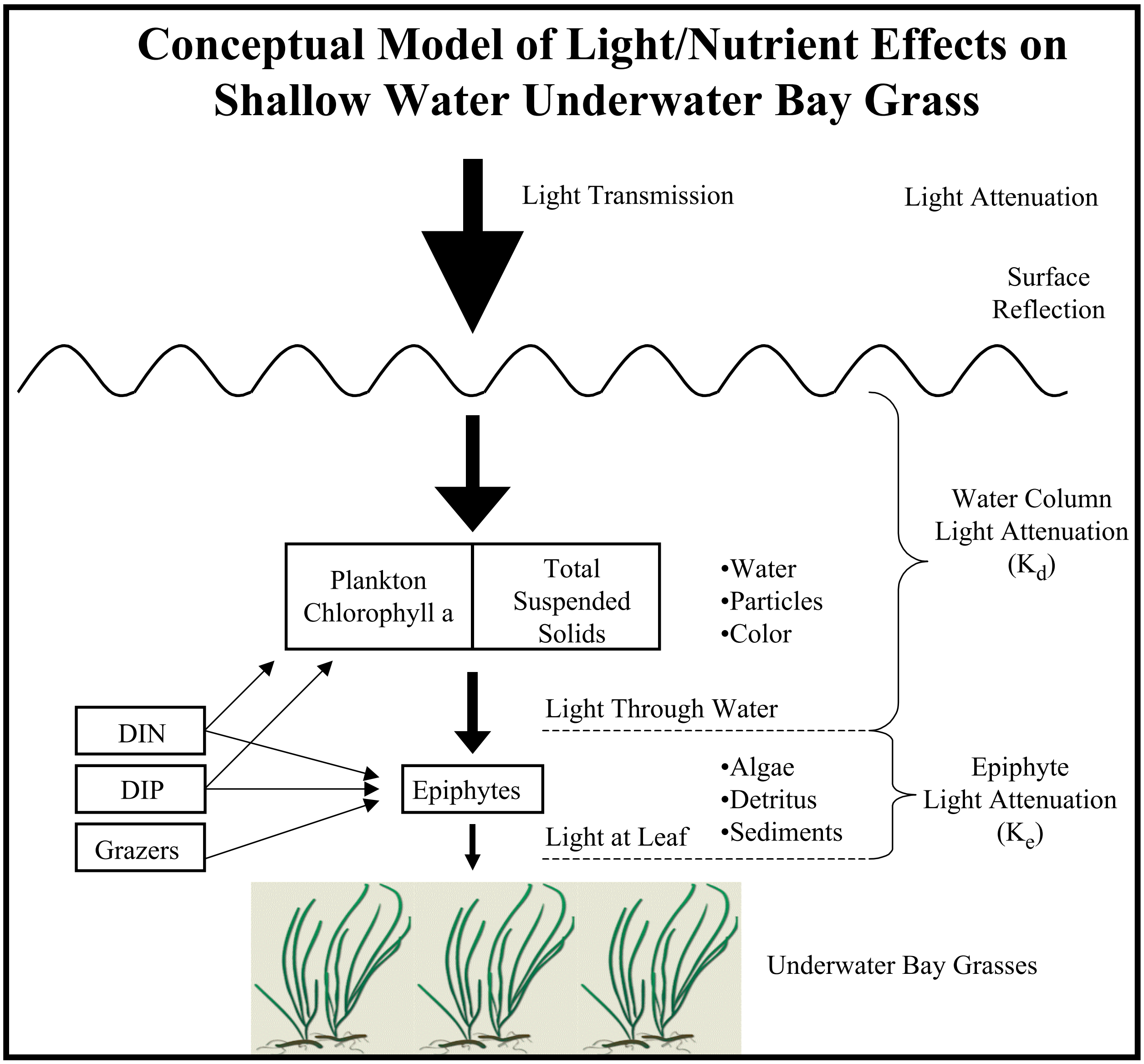

Figure 3. Availability of light for underwater bay grasses is influenced by water-column and at-the-leaf surface light attenuation processes. DIN= dissolved inorganic nitrogen. DIP= dissolved inorganic phosphorus.

sediments in the water, and associated reductions in light availability (Figure 3). Other factors such as climatic events and herbicide toxicity may also have contributed to the loss of bay grasses. In order to restore these critical habitats and food sources, enough light must penetrate the shallow waters to support the survival, growth and repropagation of diverse, healthy underwater bay grass communities.

EPA Region III has identified Chesapeake Bay water clarity criteria to establish the minimum level of light penetration required to support the survival, growth and continued propagation of bay grasses. Using a worldwide literature synthesis, an evaluation of Chesapeake Bay-specific field study findings, as well as model simulation and diagnostic tools, EPA derived Chesapeake Bay-specific water clarity criteria for low and higher salinity habitats (Table 2).

The water clarity criteria, applied only during the bay grass growing seasons, are presented in terms of the percent ambient light at the water surface extending through the water column (light-through-water) and reaching the plants' leaf surfaces (light at the leaf). The recommended light-through-water criteria can be directly measured using a Secchi disk or a light meter, whereas determining attainment of the light-at-the-leaf criteria also requires measurement of dissolved inorganic nutrients and total suspended solids concentrations. A specific depth is required in order to apply the water clarity criteria.

Table 2. Summary of Chesapeake Bay water clarity criteria for application to shallow-water bay grass designated use habitats.

Salinity Regime	**Water Clarity Criteria as Percent Ambient Light**		**Temporal Application**
	Light through Water	**Light at the Leaf**	
Tidal fresh	13 %	9 %	April 1 - October 31
Oligohaline	13 %	9 %	April 1 - October 31
Mesohaline	22 %	15 %	April 1 - October 31
Polyhaline	22 %	15%	March 1 - May 31, September 1 - November 30

CHLOROPHYLL *A* CRITERIA

Phytoplankton are small, often microscopic plants floating in the water. These organisms form the base of the Chesapeake Bay's food web, linking nutrients and sunlight energy with forage fish such as menhaden and bay anchovy, and with bottom-dwelling invertebrates such as oysters, clams and worms. The majority of the Bay's animals feed directly on phytoplankton or on organisms that consume the phytoplankton. Therefore, the Bay's "carrying capacity," or its ability to produce and maintain a diversity of species, depends in large part on how well phytoplankton meet the nutritional needs of their consumers.

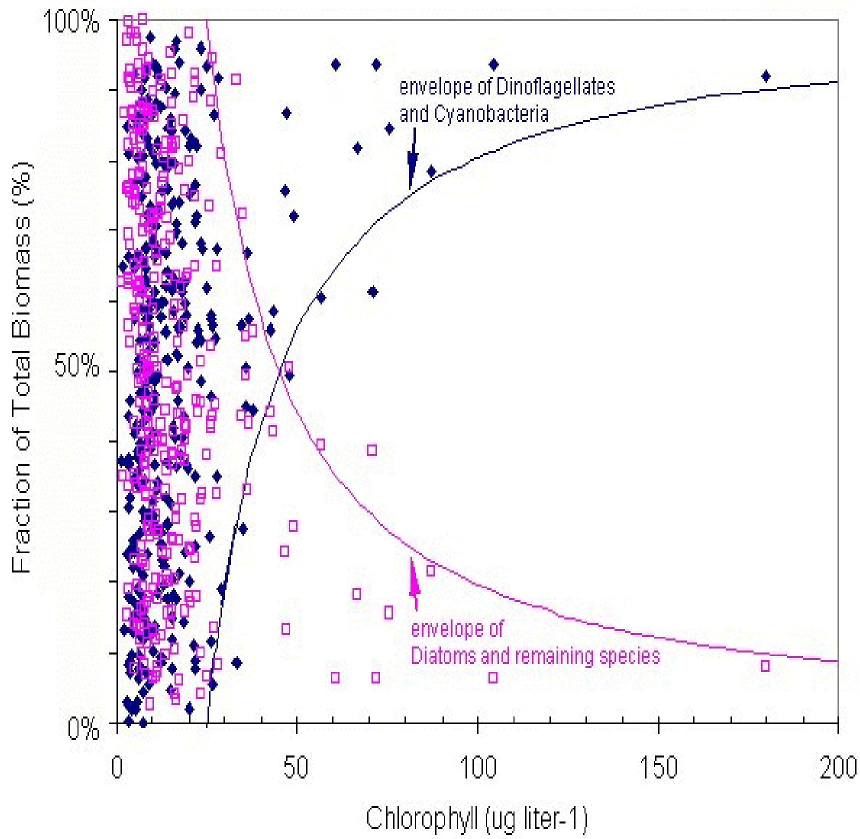

Figure 4. In natural systems, phytoplankton food composition usually does not remain the same as food quantity increases to high levels. This figure illustrates the changes that occur in food composition in summer mesohaline Chesapeake Bay waters. The fraction of total phytoplankton biomass comprised of dinoflagellates and cyanobacteria (blue green algae) increases as chlorophyll *a* increases, while the fraction of total biomass comprised of diatoms and other taxa decreases. The dinoflagellate and cyanobacteria taxonomic groups contains species with known detrimental or toxic effects on consumers, e.g. the dinoflagellates *Prorocentrum minimum, Cochlodinium heterolobatum* and *Pfiesteria piscidia*.

A primary characteristic of algae is the presence of photosynthetic pigments. Chlorophyll *a* is the primary photosynthetic pigment in algae and cyanobacteria (blue-green algae). Since chlorophyll *a* is a measure of photosynthesis, it is thus also a measure of the primary food source of aquatic food webs.

Chlorophyll *a* also plays a direct role in reducing light penetration in shallow water habitat, directly impacting underwater bay grasses. Uneaten by zooplankton and filter feeding fish shellfish, excess dead algae are consumed by bacteria, and in the process, remove oxygen from the water column. From a water quality perspective, chlorophyll *a* is the best available, most direct measure of the amount and quality of phytoplankton and the potential to lead to reduced water clarity and low dissolved oxygen impairments.

Phytoplankton assemblages can be become dominated by single species which represent poor food quality or even produce toxins that impair the animals that feed directly on them (Figure 4). Chlorophyll a concentrations have been identified that reflect potentially harmful algal blooms that have exceeded levels that cause impacts to other estuarine living resources.

EPA is providing the states with several approaches directed towards addressing regional and water-body-specific impairments related to related to the overabundance of algal biomass measured as chlorophyll *a*. The chlorophyll *a* criteria are presented as narrative (Table 3) and numerical criteria (Table 4) with supporting methodological approaches to derive more waterbody or segment specific numeric criteria.

Table 3. Chesapeake Bay narrative chlorophyll *a* criteria.

Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences–such as reduced water clarity, low dissolved oxygen, food supply imbalances, proliferation of species deemed potentially harmful to aquatic life or humans or aesthetically objectionable conditions–or otherwise render tidal waters unsuitable for designated uses.

Table 4. Chesapeake Bay chlorophyll *a* criteria concentrations characteristic of desired ecological trophic conditions and protective against water quality and ecological impairments.

Salinity Regime	**Chlorophyll *a* Concentrations (µg liter^{-1})**					
	Protective of Oligotrophic Water Quality and Ecological Conditions (seasonal mean)	Protective of Mesotrophic Water Quality and Ecological Conditions		Protective of Required Water Clarity Conditions (seasonal mean)	Protective of Required Dissolved Oxygen Conditions (seasonal mean)	Protective Against Excessive/ Harmful Algal Blooms (seasonal mean)
		mean	95%			
Spring						
Tidal Fresh	< 3	7	12	16	4	< 25-30
Oligohaline	< 3	10	23	16	5	< 25-30
Mesohaline	< 4	6	27	8	6	< 25-30
Polyhaline	< 3	3	7	8	5	< 25-30
Summer						
Tidal Fresh	< 3	9	16	16	12	< 25-30
Oligohaline	< 2	6	23	16	7	< 25-30
Mesohaline	< 5	7	16	8	5	< 25-30
Polyhaline	< 2	5	9	8	4	< 25-30

The three Chesapeake Bay criteria–dissolved oxygen, water clarity and chlorophyll *a*–should be viewed as an integrated set of criteria applied to their respective sets of designated uses habitats and addressing similar and varied ecological conditions and water quality impairments. They provide the basis for defining the water quality conditions necessary to protect the five essential Chesapeake Bay tidal water designated uses.

CRITERIA IMPLEMENTATION

EPA Region III is also presenting Chesapeake Bay criteria implementation procedures as additional guidance to the Chesapeake Bay watershed states and other agencies, institutions, groups or individuals for considering how to apply the criteria to determine the degree of attainment. EPA believe these procedures will promote consistent, baywide application of the criteria across jurisdictional boundaries.

The criteria were derived specifically to protect species and communities in the five tidal water designated uses during specific time periods. For example, dissolved oxygen criteria have been derived for application to each of the five designated uses, whereas the chlorophyll *a* criteria apply only to open-water fish and shellfish designated use habitats and the water clarity criteria only to the shallow-water bay grass designated use habitats.

In defining what it means for the criteria to be attained, stressor magnitude, duration, return frequency, spatial extent and temporal assessment period must be accounted for. Stressor magnitude refers to how much of the pollutant or condition can be allowed (e.g., 5 mg $liter^{-1}$) while still achieving the designated uses. Duration refers to the period of time over which measurements of the pollutant or water quality parameter is to be averaged (e.g., the 30 day mean). The allowable return frequency at which the criterion can be violated without a loss of the designated use also must be considered. Attainment of all three Chesapeake Bay criteria within the respective designated use habitats should be assessed at the spatial scale of the 77 Chesapeake Bay segments (spatial extent) using the most recent three consecutive years of applicable tidal water quality monitoring data (temporal assessment period).

As the estuarine habitats gradually attain the three Chesapeake Bay criteria, not only will the concentrations and values increase (i.e., dissolved oxygen and water clarity) or decrease (chlorophyll *a*), but also occurrences of short time scale extreme changes in concentrations (e.g., dissolved oxygen concentration changes from 6 mg $liter^{-1}$ to 2 mg $liter^{-1}$ in a matter of hours) will be greatly reduced. Even if the Chesapeake Bay ecosystem is fully restored, it is unlikely that a circumstance of 'zero violation' of these criteria will ever be observed, given natural Bay processes and extreme weather events. As these criteria were developed with conservative (protective) assumptions, allowing a small percentage of circumstances in which the criteria will be exceeded can still fully protect the tidal water designated uses.

The cumulative frequency distribution methodology for defining criteria attainment addresses the need to allow the criteria to be exceeded in a small percentage of instances, by integrating the five elements of criteria definition and attainment: magnitude, duration, return frequency, space and time. The methodology summarizes the frequency of instances in which the water quality threshold (e.g., chlorophyll *a* or dissolved oxygen concentration) is exceeded, as a function of the area or volume affected at a given place and over a defined period of time. Acceptable combinations of the frequency and spatial extent of such instances are defined using a biologically based reference curve.

Using this approach to define criteria attainment, EPA recommends a procedure to quantify the spatial extent (area or volume) to which the water quality criterion has been exceeded for each monitoring event. For example, under a monthly monitoring program, the spatial extent to which the criterion has been exceeded would be estimated for each month. This could be accomplished using interpolation software to insert point or transect data; by analyzing remote-sensing data that provides continuous spatial coverage; or by statistical estimation from probability-based samples. The criteria measure could thus be estimated at all locations in a given spatial unit. The spatial extent to which a water quality criterion had been exceeded for a given monitoring event would be defined as the fraction of the total area or volume (expressed as a percent) that exceeds the criterion.

Through the application of coupled airshed, watershed and tidal water quality Chesapeake Bay models, the reductions in air, land, and water-based loadings of nitrogen, phosphorus and sediments required to attain the criteria defined ambient tidal water concentrations of dissolved oxygen, water clarity and chlorophyll *a* can be directly determined. In effect, conditions necessary for attainment of the three sets of Chesapeake Bay water quality criteria can be translated into watershed-based caps on nutrient and sediment loadings and further allocated to specific sources and locations within those watersheds.